Chapter 3. Microbiology

INTRODUCTION

The City of San Diego performs water quality monitoring along the shoreline and in offshore ocean waters for the region surrounding the South Bay Ocean Outfall (SBOO). This aspect of the City's ocean monitoring program is designed to assess general oceanographic conditions, evaluate patterns in movement and dispersal of the SBOO wastewater plume, and monitor compliance with water contact standards defined in the 2001 California Ocean Plan (COP) as according to NPDES permit specifications (see Chapter 1). Results of all sampling and analyses, including COP compliance summaries, are submitted to the San Diego Regional Water Quality Control Board and the International Boundary and Water Commission in the form of monthly receiving waters monitoring reports. Densities of indicator bacteria (total coliforms, fecal coliforms, enterococcus), along with oceanographic data (see Chapter 2), are evaluated to provide information about the movement and dispersion of wastewater discharged to the Pacific Ocean through the outfall. Analyses of these data may also help identify other point or non-point sources of bacterial contamination in the region (e.g., outflows from rivers or bays, surface runoff from local watersheds). This chapter summarizes and interprets patterns in seawater bacterial concentrations collected for the South Bay region during 2007.

Materials and Methods

Field Sampling

Seawater samples for bacteriological analyses were collected at a total of 51 fixed shore or offshore sampling sites during 2007 (**Figure 3.1**). Sampling was performed weekly at 11 shore stations to monitor bacterial levels along public beaches. Eight of the shore stations (S4, S5, S6, S8, S9, S10, S11, S12), located between the USA/Mexico border and Coronado, southern California, are subject to COP water contact standards (see **Box 3.1**). The other three shore stations (S0, S2, S3) located south of the border are not subject to COP requirements. In addition, 28 stations were sampled in offshore waters to monitor levels of indicator bacteria. These offshore sites are located in a grid surrounding the outfall along the 9, 19, 28, 38, and 55-m depth contours. Three of the offshore sites (stations I25, I26 and I39) are considered kelp bed stations because of their proximity to the Imperial Beach kelp bed. These three stations are subject to the COP water contact standards and are each sampled five times per month. The remaining 25 offshore stations are sampled once a month, usually over a 3-day period.

Seawater samples from the 11 shore stations were collected from the surf zone in sterile

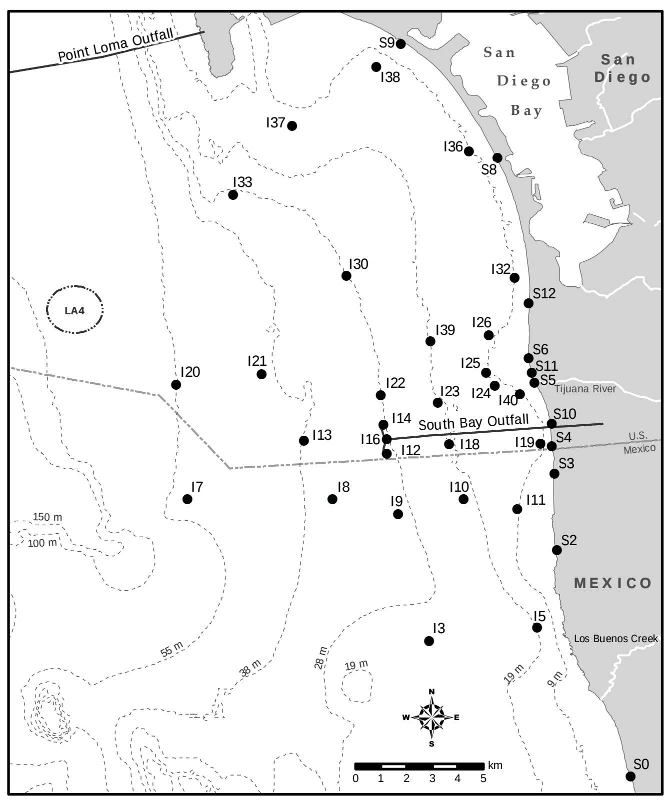

Figure 3.1
Water quality monitoring stations for the South Bay Ocean Outfall Monitoring Program.

Box 3.1

Bacteriological compliance standards for water contact areas, 2001 California Ocean Plan (SWRCB 2001). CFU = colony forming units.

(1) *30-day total coliform standard* — no more than 20% of the samples at a given station in any 30-day period may exceed a concentration of 1000 CFU per 100 mL.

(2) *10,000 total coliform standard* — no single sample, when verified by a repeat sample collected within 48 hrs, may exceed a concentration of 10,000 CFU per 100 mL.

(3) *60-day fecal coliform standard* — no more than 10% of the samples at a given station in any 60-day period may exceed a concentration of 400 CFU per 100 mL.

(4) *geometric mean* — the geometric mean of the fecal coliform concentration at any given station in any 30-day period may not exceed 200 CFU per 100 mL, based on no fewer than 5 samples.

250-mL bottles. In addition, visual observations of water color and clarity, surf height, human or animal activity, and weather conditions were recorded at the time of collection. The samples were then transported on blue ice to the City of San Diego's Marine Microbiology Laboratory (CSDMML) and analyzed to determine concentrations of total coliform, fecal coliform, and enterococcus bacteria.

Seawater samples were collected at three discrete depths at each of the kelp bed and other offshore sites and analyzed for the above indicator bacteria (total and fecal coliforms, enterococcus), total suspended solids (TSS), and oil and grease. These samples were collected using either an array of Van Dorn bottles or a rosette sampler fitted with Niskin bottles. Aliquots for each analysis were drawn into appropriate sample containers. Seawater samples for bacteriological analysis were refrigerated on board ship and transported to the CSDMML for analysis. The TSS and oil and grease samples were taken to the City's Wastewater Chemistry Laboratory for analyses. Visual observations of weather conditions, sea state, and human or animal activity in the area were also recorded at the time of sampling. Monitoring of the SBOO area and neighboring coastline also included aerial and satellite image analysis performed by Ocean Imaging of Solana Beach, California (Svejkovsky 2008; see also Chapter 2).

Laboratory Analyses and Data Treatment

All bacterial analyses were performed within 8 hours of sample collection and conformed to standard membrane filtration techniques (see APHA 1992). The CSDMML follows guidelines issued by the EPA Water Quality Office, Water Hygiene Division, and the California State Department of Health Services (CDHS) Environmental Laboratory Accreditation Program (ELAP) with respect to sampling and analytical procedures (Bordner et al. 1978, APHA 1992).

Colony counting of indicator bacteria, calculation of results, data verification and reporting all follow guidelines established by the EPA (Bordner et al. 1978) and APHA (1992). According to these guidelines, plates with bacterial counts above or below the ideal counting range were given greater than (>), less than (<), or estimated (e) qualifiers. However, these qualifiers were dropped and the counts treated as discrete values during calculation of mean values and in determining compliance with COP standards.

Quality assurance tests were performed routinely on seawater samples to ensure that sampling variability did not exceed acceptable limits. Duplicate and split bacteriological samples were processed according to method requirements to measure intra-sample and inter-analyst variability, respectively. Results of these procedures were reported in the laboratory's Quality Assurance Report for 2007 (City of San Diego 2008).

COP and AB 411 (CDHS 2000) bacteriological benchmarks were used as reference points to distinguish elevated bacteriological values in receiving water samples discussed in this report. These benchmarks are: (a) >1000 CFU/100 mL for total coliforms; (b) >400 CFU/100 mL for fecal coliforms; (c) >104 CFU/100 mL for enterococcus. Furthermore, seawater samples with total coliform concentrations ≥1000 CFU/100 mL and fecal:total (F:T) ratios ≥0.1 are considered representative of contaminated waters (see CDHS 2000). Samples that met these latter criteria were used as indicators of the SBOO waste field or other sources of contamination.

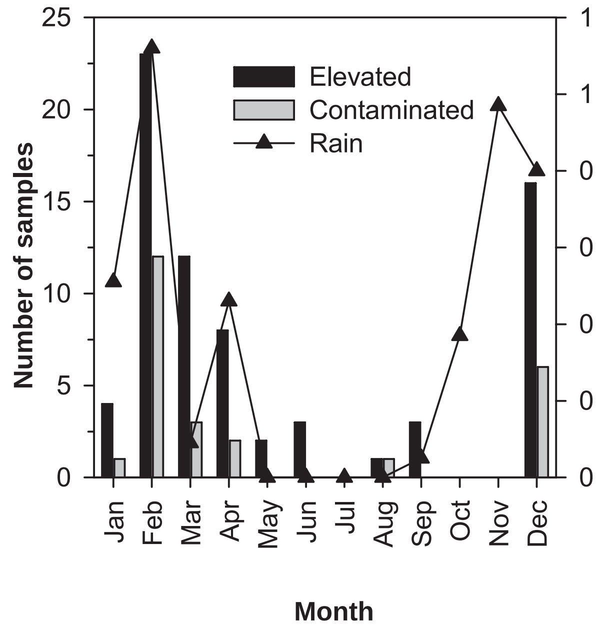

Figure 3.2
Comparison of monthly rainfall to total coliform concentrations in samples from SBOO shore stations collected during 2007. Elevated=number of samples with total colifom densities ≥1000 CFU/100 mL; Contaminated=number of samples with total coliform densities ≥1000 CFU/100 mL plus a F:T ratio ≥0.1. Rain was measured at Lindbergh Field, San Diego, CA. It should be noted 96% of the rainfall in November occurred on November 30.

Results and Discussion

Shore Stations

Concentrations of indicator bacteria were generally very low along the South Bay shoreline in 2007, which likely reflects the relatively low rainfall that occurred during the year (see **Appendix B.1**). Monthly densities averaged 6 to 10,676 CFU/100 mL for total coliforms, 2 to 4234 CFU/100 mL for fecal coliforms, and 2 to 3018 CFU/100 mL for enterococcus. As expected, the highest bacterial densities occurred during the wet season (**Figure 3.2**). This was particularly true for February, which was the wettest month of the year. MODIS satellite imaging of the region on February 20 showed turbidity plumes from the Tijuana River and Los Buenos Creek (in Mexico) encompassing several of the shore stations, all of which had elevated bacteria levels (**Figure 3.3**). These types of turbidity plumes were observed repeatedly following rain events during the year (Svejkovsky 2008). In contrast to the wet season, bacterial contamination along the shore was sporadic during periods of warmer, dry conditions from May through October. For example, only one out of 30 samples collected in June had total coliform concentrations >10,000 CFU/100 mL, and only one out of 24 samples from August had a F:T ratio ≥0.1 (**Appendix B.2**). Both of these samples were collected at southernmost station S0 located in Mexico.

The general relationship between rainfall and levels of indicator bacteria has remained consistent since sampling began in 1995 (**Figure 3.4**). This is particularly evident at shore stations located nearest the Tijuana River (stations S2-S6, S10, and S11) and Los Buenos Creek (station S0). Historically these stations have had higher levels of fecal coliforms than stations located further north (e.g., S8 and S9; City of San Diego 2007a). Contaminated waters originating from the Tijuana River and Los Buenos Creek during periods of increased flows (e.g., during storms or extreme tidal exchanges) are likely sources of bacteria for nearby monitoring sites (see Largier et al. 2004).

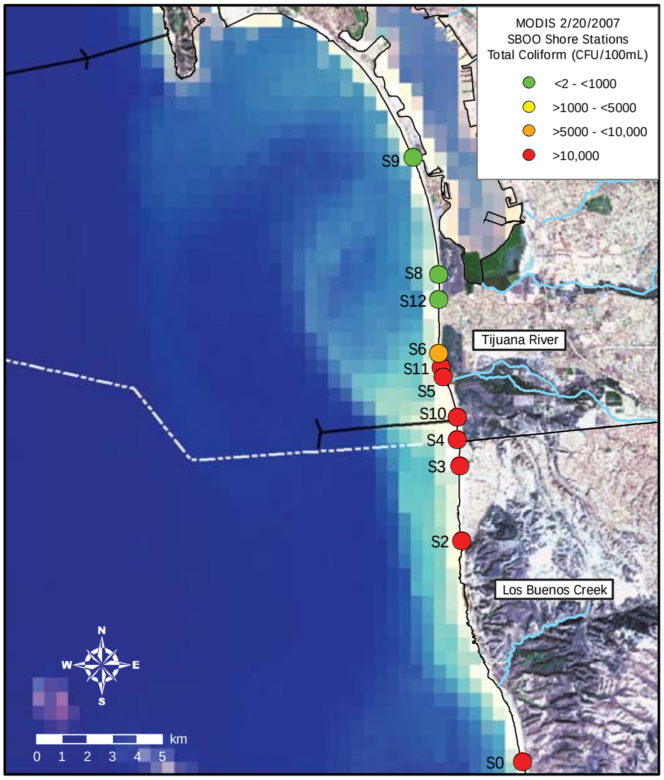

Figure 3.3

MODIS satellite imagery showing the SBOO monitoring region on February 20, 2007 (Svejkovsky 2008) combined with total coliform concentrations at shore stations sampled on the same day. Turbid waters from the Tijuana River and Los Buenos Creek can be seen moving north along the coastline, overlapping stations with higher levels of contamination. Waters are clear over the outfall discharge site.

Such contaminants may be from upstream sources, including sod farms, surface runoff not captured by the canyon collector system, the Tijuana estuary (e.g., decaying plant material), and partially treated effluent from the San Antonio de los Buenos Wastewater Treatment Plant (in Mexico) that ends up in Los Buenos Creek.

Kelp Stations

There was no evidence that the wastewater plume from the SBOO impacted any of the three kelp stations in 2007. Instead, elevated levels of indicator bacteria at these sites corresponded to periods of heavy rainfall similar to the pattern seen at the shore stations. For example, all 13 of the instances where total coliform concentrations were

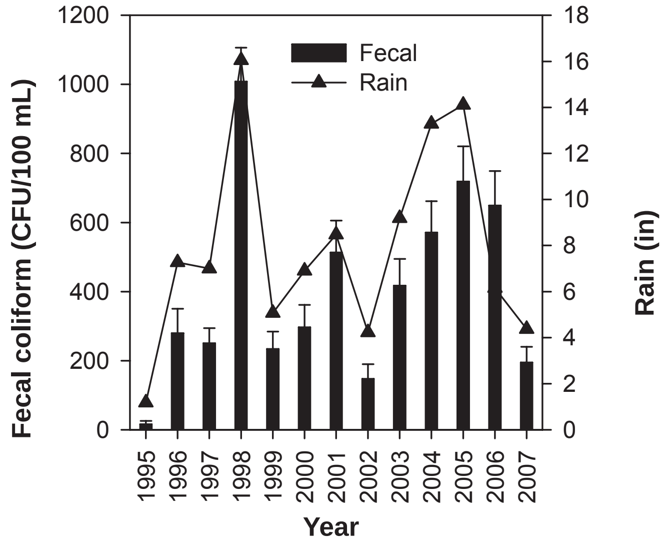

Figure 3.4

Comparison of annual rainfall to fecal coliform concentrations in samples from SBOO shore stations collected between 1995 and 2007. Fecal concentrations are expressed as mean±SE per year. Rain for 1995 includes only October–December. Rain was measured at Lindbergh Field, San Diego, CA.

elevated (i.e., ≥ 1,000 CFU/100mL) at the kelp stations occurred during February when rainfall was greatest for the year (**Table 3.1**). Furthermore, MODIS imagery for February 21 indicated such a rain-influenced turbidity plume moving northeast from the Tijuana River and encompassing all of the kelp stations (**Figure 3.5**). While some elevated levels of total coliform bacteria occurred in 2007, enterococcus bacteria exceeded benchmark values (104 CFU/100 mL) on only five occasions during February, March, and July (see City of San Diego 2007b, c, d), and fecal coliforms never exceeded benchmark values (400 CFU/100 mL).

Oil and grease and total suspended solids (TSS) are also measured at the kelp stations as potential indicators of wastewater. However, previous analyses have demonstrated that these parameters have limited utility as indicators of the waste field (City of San Diego 2007a). Oil and grease concentrations were mostly below the detection limit (<1.4 mg/L) in 2007; the only exception was a value of 1.5 mg/L at station I39 in September (**Table 3.2**). TSS varied considerably during the year, ranging between 1.7 and 22.8 mg/L per sample. Of the 15 seawater samples with

Table 3.1 Summary of samples with elevated total coliform concentrations (> 1000 CFU/100 mL) collected at SBOO kelp stations during 2007. Values are expressed as CFU/100 mL; Total=total coliform; Fecal=fecal coliform; F:T=fecal to total coliform ratio.

Station	Date	Depth	Total	Fecal	F:T
I25	February 2	2	11,000	140	0.013
I25	February 2	6	>16,000	100	0.006
I25	February 2	9	3400	34	0.010
I26	February 2	2	4000	18	0.005
I26	February 2	6	2400	28	0.012
I26	February 2	9	2600	16	0.006
I39	February 2	2	1200	2	0.002
I25	February 21	2	5200	160	0.030
I25	February 21	6	4200	94	0.020
I25	February 21	9	5200	110	0.020
I26	February 21	2	3200	74	0.020
I26	February 21	6	1400	50	0.040
I26	February 21	9	1600	72	0.050
I39	February 21	2	2000	56	0.030
I39	February 21	12	2000	58	0.030
I39	February 21	18	1200	26	0.020

elevated TSS concentrations (≥10.0 mg/L), only one corresponded to a sample with elevated levels of indicator bacteria (i.e., total coliforms >1000 CFU/100 mL). In contrast, five of these high TSS samples occurred at bottom depths; were likely due to re-suspension of bottom sediments when the CTD reached the sea floor. The remaining nine represented surface-water samples most likely associated with plankton blooms (see Chapter 2).

Offshore Stations

Monthly sampling of indicator bacteria at the other 25 offshore stations also showed some trends related to rainfall (**Figure 3.6**) or to proximity to the outfall discharge site. Forty-three out of the 900 samples collected at these sites during 2007 had total coliform levels above benchmark values (**Table 3.3**). Of these, 18 samples also exceeded the fecal coliform benchmark, while seven of the samples had a fecal to total coliform ratio indicative of contaminated waters (i.e., F:T ≥0.1). A total of 21 samples were collected during the wet season at depths between 2 and 12 m, 18 of which were from nearshore stations I18, I19, I23, I24, and I40. As with the shore and kelp stations,

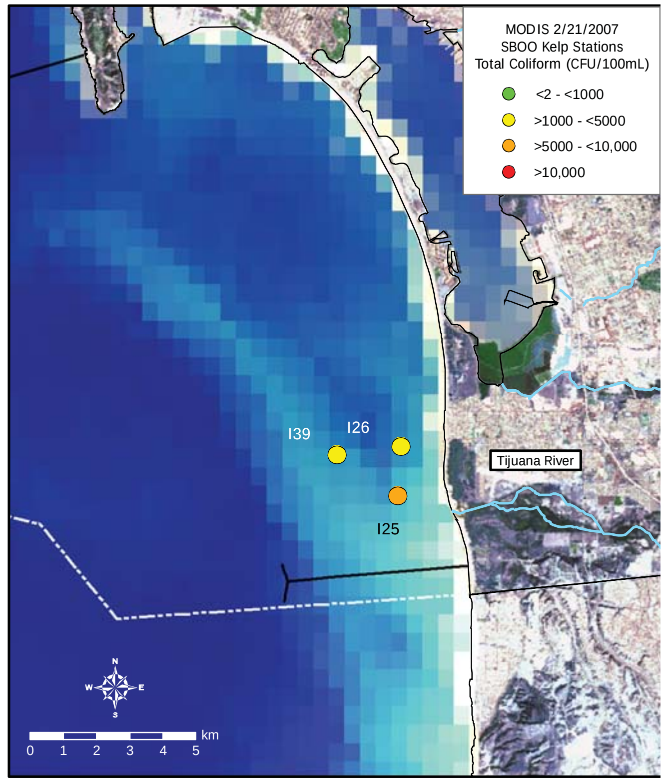

Figure 3.5
MODIS satellite image showing the SBOO monitoring region on February 21, 2007 (Svejkovsky 2008) combined with total coliform concentrations at kelp stations sampled on the same day. Turbid waters from the Tijuana River and Los Buenos Creek can be seen moving north along the coastline overlapping the kelp stations. Waters are clear over the outfall discharge site.

evidence from the MODIS satellite imaging suggests that the nearshore region is being affected by turbidity (contaminant) plumes originating from the Tijuana River and Los Buenos Creek. For example, a MODIS image taken on February 21 indicated that a turbidity plume associated with increased rainfall had a northeast trajectory that encompassed stations I18, I19, I23, I24, and I40, which were all sampled on the same day (**Figure 3.7**). Samples collected at these five stations on that day were found to have coliform levels that exceeded benchmark values. In contrast, stations located in close proximity to the SBOO (i.e., 12, I14, I16, and I22) sampled on that day had low levels of indicator bacteria at all depths. All other offshore samples also had low coliform levels in February.

Elevated levels of indicator bacteria were also detected at a few other sites during the year.

Table 3.2

Summary of oil and grease and total suspended solid concentrations in samples collected from kelp stations in 2007. The method detection limits are 1.4 mg/L for O&G and 1.6 mg/L for TSS; (n=number of samples with detected concentrations).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oil & Grease												
n	0	0	0	0	0	0	0	0	1	0	0	0
Min	—	—	—	—	—	—	—	—	1.5	—	—	—
Max	—	—	—	—	—	—	—	—	1.5	—	—	—
Mean	—	—	—	—	—	—	—	—	1.5	—	—	—
Total Suspended Solids												
n	9	9	9	9	9	9	9	9	9	9	9	9
Min	3.3	4.7	3.8	2.3	1.7	3.6	4.1	7.5	2.0	2.6	3.8	1.7
Max	8.1	10.2	22.8	6.8	7.6	9.4	10.3	13.2	10.3	15.0	11.5	6.7
Mean	5.1	6.3	8.1	4.1	3.2	5.4	6.5	11.3	3.5	6.4	5.7	3.4

Thirteen of the above 43 samples with elevated total coliforms were collected at stations I12 and I16 located immediately adjacent to the SBOO (see Table 3.3). Eleven of these samples were collected at depths of 18 m or deeper, of which six exceeded the fecal coliform benchmark; three of these samples had F:T ratios indicative of contaminated waters. An additional five samples were collected at stations I9 (located south of the outfall) or I21 (located northwest of the outfall). Overall, these results support the observation that the SBOO wastewater plume remained subsurface and offshore during most of 2007.

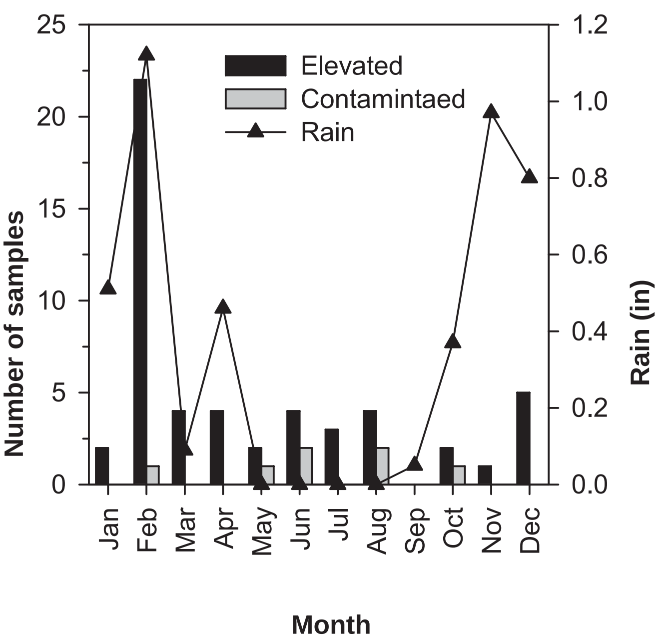

Figure 3.6

Comparison of monthly rainfall to total coliform concentrations in samples from SBOO offshore stations collected during 2007. Elevated=number of samples with total coliform densities ≥1000 CFU/100 mL; Contaminated=number of samples with total coliform densities ≥1000 CFU/100 mL plus a F:T ratio ≥0.1. Rain was measured at Lindbergh Field, San Diego, CA. It should be noted 96% of the rainfall in November occurred on November 30.

A comparison of fecal coliform densities in 2007 to those from both the pre-discharge period (1995-1998) and prior post-discharge period (1999-2006) demonstrates that while bacteria levels were higher during the post-discharge years through 2006 than during the pre-discharge period, concentrations of indicator bacteria in 2007 were quite low compared to both periods at most depths (**Figure 3.8A**). Average fecal densities were highest for samples collected during the post-discharge period at a depth of 18 m (Figure 3.8A), primarily from stations I12, I14 and I16 located near the SBOO diffusers (Figure 3.8B).

As at the kelp stations, oil and grease concentrations were mostly below the detection limit (<1.4 mg/L) at the other offshore stations in 2007, while TSS concentrations varied considerably during the year (**Appendix B.3**). Oil and grease was detected in only four samples, including two from August (3.5 mg/L at station I13; 2.7 mg/L at station I10), one from September (1.9 mg/L at station I14) and one from

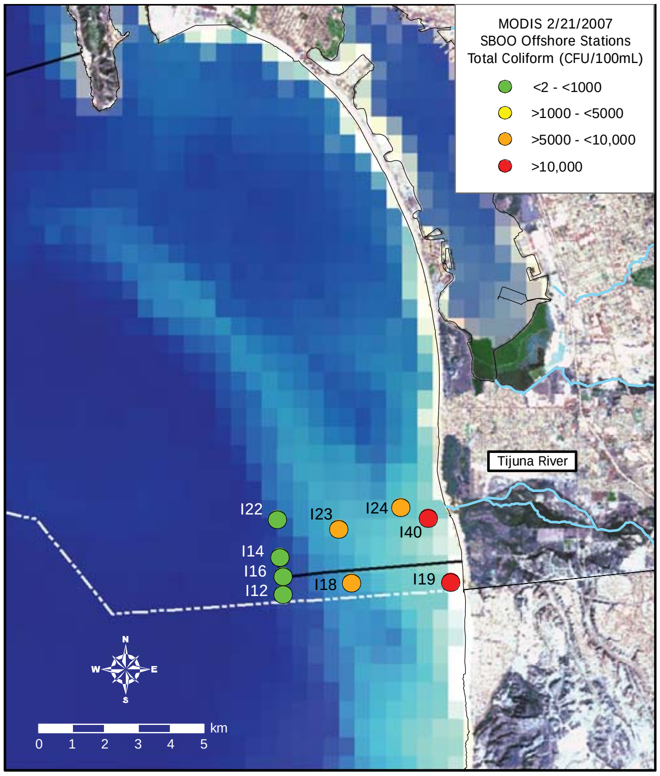

Figure 3.7
MODIS satellite image showing the San Diego monitoring region on February 21, 2007 (Svejkovsky 2008) combined with total coliform concentrations at offshore stations sampled on the same day. Turbid waters from the Tijuana River and Los Buenos Creek can be seen moving north along the coastline and overlapping stations where contamination was high. Waters are clear over the outfall discharge site.

October (1.6 mg/L at station I21). Values of TSS ranged between 1.6 and 28.9 mg/L per sample. Of the 77 samples with elevated TSS concentrations (≥10.0 mg/L), only 6% corresponded to samples with total coliform densities >1000 CFU/100 mL. None of these samples had an F:T ratio ≥0.1. In contrast, 30% occurred at bottom depths, likely due to the re-suspension of bottom sediments when the CTD reached the sea floor, and 58% were surface samples, most likely associated with plankton blooms that occurred during the year (see Chapter 2).

California Ocean Plan Compliance

Compliance with the 2001 COP water contact standards for samples collected (in 2007) at the shore and kelp bed stations located north of the USA/Mexico

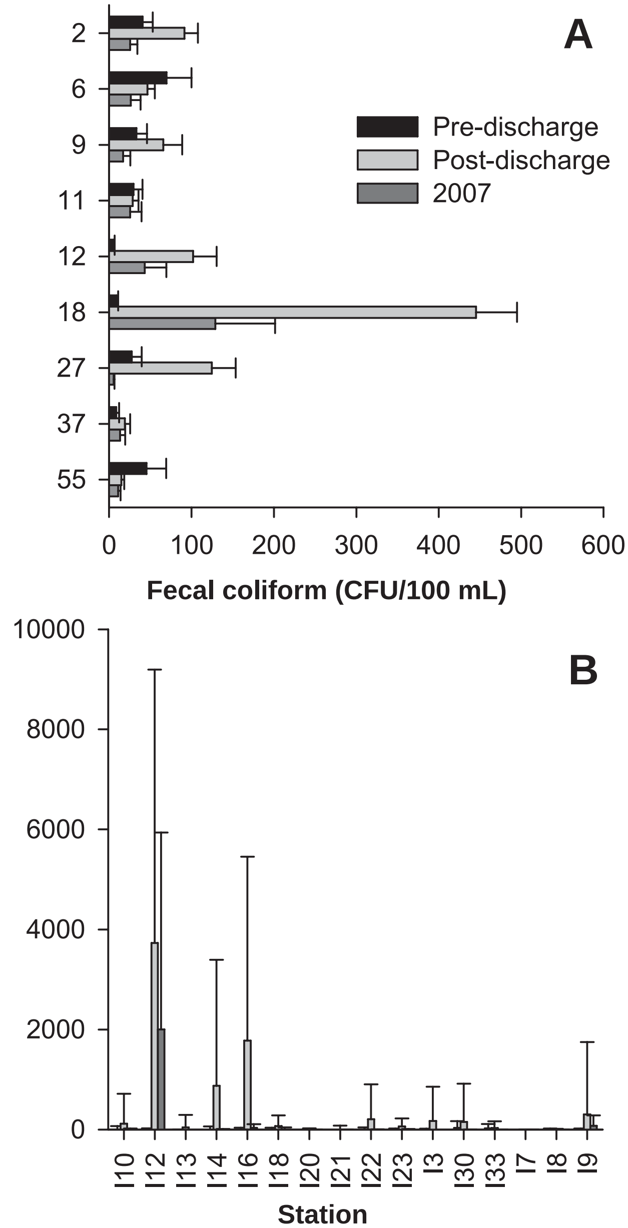

Figure 3.8
Summary of fecal coliform concentrations at SBOO offshore stations sampled in 2007 versus pre-discharge (1995-1998) and post-discharge periods (1999-2006) by depth (A) and by station (B). Values are expressed as means±SE.

border is summarized in **Appendix B.4**. Overall, compliance has increased over the last two years, which is probably related to the drought conditions and relatively low rainfall that occurred during 2006 and 2007 (see City of San Diego 2007a). Compliance for the 30-day total coliform standard at the shore stations ranged from 63 to 100% in 2007 compared to 49-95% in 2006 and 36-81% in 2005. In addition, the number of days that shore samples were out of

Table 3.4

Summary of oil and grease and total suspended solid concentrations in samples collected from offshore stations in 2007. The method detection limits are 1.4 mg/L for O&G and 1.6 mg/L for TSS; n=number of samples with detected concentrations.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oil & Grease												
n	0	0	0	0	0	0	0	2	1	1	0	0
Min	—	—	—	—	—	—	—	2.7	1.9	1.6	—	—
Max	—	—	—	—	—	—	—	3.5	1.9	1.6	—	—
Mean	—	—	—	—	—	—	—	3.1	1.9	1.6	—	—
Total Suspended Soilds												
n	82	82	83	81	74	77	83	82	69	80	68	77
Min	3.1	2.9	3.5	2.3	1.6	1.8	2.4	2.0	2.2	2.2	1.8	2.1
Max	14.1	28.9	18.1	27.6	11.6	14.4	21.4	15.5	14.0	18.6	13.5	18.8
Mean	5.9	6.6	6.8	5.5	4.5	4.9	6.0	7.6	4.8	4.6	3.9	4.6

compliance with the 10,000 total coliform standard decreased from 41 in 2005, to 28 in 2006, to six in 2007. The frequency of compliance with the 30-day total and 30-day geometric mean standards was lowest in February–May and December, which corresponded to periods when the cumulative rainfall was greatest. All shore stations were 100% compliant with the 60-day fecal standard.

As in the previous years, rainfall caused low compliance rates for the shore stations located closest to the Tijuana River, whereas the three northernmost shore stations (S8, S9, S12) were 100% compliant with all coliform standards. Percent compliance at the more southern stations ranged from 63 to 88% for the 30-day total coliform and 30-day geometric mean standards. Stations S4, S5 and S10 were responsible for nearly all of the reduced compliance for three standards. The proximity of these stations to the Tijuana River is considered the likely reason for the frequency with which they are out of compliance (Largier et al. 2004; City of San Diego 2007a). Less surface runoff and more frequent southerly longshore currents during 2007 probably contributed to the increased compliance at stations north of the Tijuana River compared to previous years (see City of San Diego 2007a).

Samples collected at kelp stations I25, I26 and I39 were 100% compliant with the 10,000 total coliform standard, the 60-day fecal coliform standard, and the fecal geometric standard in 2007. In contrast, the 30-day total coliform standard was exceeded at least once at each of these stations in February and March after periods of heavy rainfall. Although there was not a tremendous amount of rain in March, the above exceedences occurred at the beginning of the month following a large storm at the end of February.

Summary and Conclusions

Densities of indicator bacteria at individual shore and kelp stations sampled in the South Bay region were lower overall in 2007 than in previous years. Consequently, this resulted in higher rates of compliance with the 2001 COP standards. Although elevated bacterial densities were detected occasionally along the shore, and at the kelp and other nearshore stations throughout the year, these data do not indicate shoreward transport of the SBOO wastewater plume. Instead, indicator bacteria and satellite imagery data indicate that sources such the Tijuana River, Los Buenos Creek, and surface runoff associated with rainfall events are more likely to impact water quality along and near the shore. For example, shore stations located near the Tijuana River and Los Buenos Creek historically have higher levels of fecal coliform than stations further to the north. Further, long-term analyses of various water quality parameters have demonstrated that the general relationship between rainfall and elevated bacteria levels has remained consistent since ocean monitoring began in 1995.

The infrequent occurrence of indicator bacteria at depths shallower than 12 m at the offshore stations indicates that the wastewater plume from the SBOO rarely reached surface waters in 2007. The majority of water quality samples indicative of wastewater was collected from depths of 18 m and below, at stations nearest the SBOO discharge site, or offshore throughout the year. Thermal stratification present from April through October likely prevented the plume from surfacing most of the year; this was supported by DMSC aerial imagery that detected the outfall plume's near-surface signature on several occasions when the water column was mixed during January–March, November and December (see Chapter 2).

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